Differentiable Planetary Spectrum Model as a Foundation Software for Exoplanet Atmosphere Characterization

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In the field of exoplanet atmospheric spectroscopy, the advent of space-based precision spectroscopy by JWST and the maturation of high-dispersion spectroscopic instruments on ground-based large telescopes, such as IRD/REACH, CRIRES+/HiRISE, KPIC and so on, have enabled highly accurate comparisons between models and data. Consequently, there has been an increasing need for statistical inference using complex atmospheric models with numerous parameters, as well as for improvements in the accuracy of molecular line databases. To bridge the gap between precise data and complex models, we have developed ExoJAX (Kawahara, Kawashima, Masuda+2022), an auto-differentiable spectrum model utilizing Google/JAX. As examples of its application, we refer to the Bayesian inference of atmospheric characterization of brown dwarfs through high-dispersion spectra using HMC-NUTS (see presentations by Mr. Hibiki Yama and Dr. Yui Kasagi), and experiments measuring the pressure line widths of methane, which becomes important in the atmospheres of hot exoplanets (refer to Mr. Ko Hosokawa's presentation). This report will cover the further applications of this planetary spectrum code, specifically the implementation and future prospects of medium to high-dispersion transmission light spectra, and reflected/scattered spectra. Notably, the latter includes the implementation of the flux-adding method, an efficient solution for the two-stream approximation, in an automatically differentiable manner. Test results using high-dispersion reflected spectra of Jupiter are also planned to be presented.

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